

Structure and Magnetic Behaviors of melt-spun $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ alloy Containing Icosahedral

Wanqiang Liu¹, Ruiping Deng², Limin Wang²

¹School of Materials Science and Engineering, Changchun University of Science and Technology, Changchun 130022, China

²State Key Laboratory of Rare Earth Resource Utilization, Changchun Institute of Applied Chemistry, CAS, Changchun 130022, China
Email: wqliu1979@126.com

(Abstract) The ribbons of $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ and TiVNi alloys were synthesized by arc-melting and subsequent melt-spinning techniques. The structures and magnetic properties were investigated. The results showed that the icosahedral quasicrystal, Ti_2Ni -type face centered cubic phase and body centered cubic structural solid solution phase existed in $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ alloy, and the Ti_2Ni -type FCC phase and BCC solid solution phase presented in TiVNi alloy. The relationships of magnetization - magnetic field and M-T(magnetization - temperature of the alloy ribbons were investigated by using Superconductivity Quantum Interference Device. The results demonstrated that the magnetic behavior was different, which is the $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ alloy ribbons exhibited higher ferromagnetic properties than those of TiVNi alloy ribbons both at 15 and 300 K.

Keywords: Alloys; Magnetic properties; Magnetic behavior; Icosahedral quasicrystal; Ferromagnetic properties

1. INTRODUCTION

This Since quasicrystalline alloy was first observed in 1984, a number of icosahedral quasicrystalline phases (I-phase) have been successfully obtained. One of the most interesting challenges in quasicrystal research is the discovery of relationship between the unusual structural and the physical properties of these materials. In particular, it may be expected that the non-periodicity of the atomic arrangement influences the electronic and magnetic properties of quasicrystals. The structural and physical characteristics of Ti-based quasicrystals are still interesting in terms of the structural stability [1, 2] and potential applications in hydrogen storage materials [3, 4]. The magnetic ordering of localized spins in quasiperiodic structures is also a fundamental issue for study.

Among Ti-based quasicrystals, Ti-Zr-Ni alloys are known to be the best ordered of forming quasicrystal without silicon, comparing with two exceptions, Ti-Zr-Co and Ti-Zr-Fe [5, 6]. Although the structure, electrochemical characteristics and mechanical properties of quasicrystals have been lively researched [7, 8], few studies on the magnetic properties have yet been reported. Two kinds of magnetic quasicrystals have been investigated so far. The one belongs to the icosahedral i-AlPdMn and i-AlCuFe families, where the *d* electrons of the transition metal elements represent the reoriented magnetic dipoles [9,10]. The o is the rare earth (RE) containing icosahedral families RE-Mg-Zn and RE-Mg-Cd, where the magnetic moments of *f* electrons of the rare earth atoms are sizable and well localized [9,11,12]. For Ti-based quasicrystals, only a few results were reported about the magnetic properties, including the magnetic susceptibilities of Ti-Cr-Si-O alloys [13], the magnetic behaviors of $\text{Ti}_{50}\text{Zr}_{33}\text{Ni}_{17}$ [14], the superconductivity property of quasicrystals dominant Ti-Zr-Ni

alloy [15], and combined with the role of hydrogen in magnetism [16].

In this work, we investigated the magnetic properties of melt-spinning $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ and TiVNi alloys by using SQUID, in order to further understand the magnetic properties of $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ quasicrystals.

2. EXPERIMENTAL PROCEDURE

Pieces of Ti, V, Ni with purities higher than 99.9% were arc-melted in an argon atmosphere on a Cu hearth which is cooled by water. To minimize the oxygen contamination, the sample chamber was evacuated to 10^{-5} torr and was back and forth filled with high purity argon gas for three times. For the homogeneity of the samples, the ingots were melted at least three times and were flipped at each melting-cooling cycle. The $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ and TiVNi alloy ribbons of about 2.5 mm in width and 35 μm in thickness were prepared by a single roller melt-spinning technique under an argon atmosphere. The circumferential velocity of the copper wheel was 34 m/s. This technique could achieve a cooling rate from 10^5 to 10^6 $^{\circ}\text{C}/\text{s}$, which is fast enough to solidify the liquids and form a non-equilibrium phase. The phase of the as-obtained ribbons was determined by X-ray diffraction (XRD). The magnetization measurements were carried out at the range of 15-300 K using a MPMS-XL-7 SQUID magnetometer, Quantum Design Co. LTD, USA.

3. RESULTS AND DISCUSSION

3.1 Phase structure

Figure 1 shows the XRD patterns of the $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ and the TiVNi alloys. From Fig. 1 (a), all diffraction peaks of the $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ alloy could be indexed to the I-phase, Ti_2Ni -type

face centered cubic (FCC) phase and body centered cubic (BCC) solid solution phase. Fig. 1 (b) shows that the XRD pattern of the TiVNi indexes Ti_2Ni -type face centered cubic (FCC) phase and body centered cubic (BCC) solid solution phase.

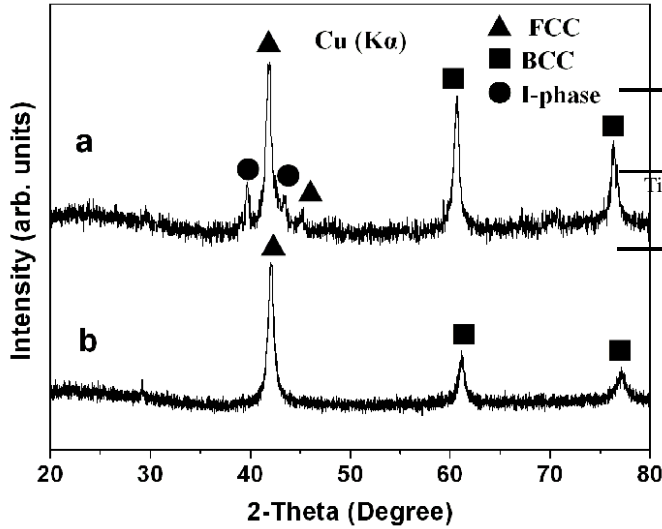


Figure. 1 XRD patterns of (a) $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ and TiVNi alloys

We performed TEM examination of the $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}_{0.94}$ ribbon. Figure 2 was the bright field image displaying the typical growth morphology and the mottled appearance of the I-phase nodules (indicated as I). The size of the nodules varied from approximately 200 nm 300 nm. In diffraction studies for the point group symmetry of the I-phase, the expected 2-fold electron diffraction patterns (EDPs) were observed as shown in Figure 2. In 2-fold symmetry orientation, the weak diffraction spots were triangular and the more intense spots were elongated and became elliptical.

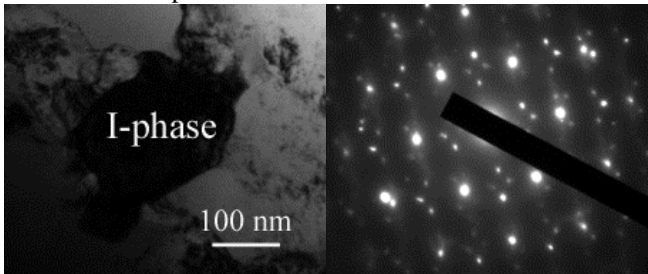


Figure 2 TEM image of the melt-spun $\text{Ti}_{1.4}\text{V}_{0.4}\text{Ni}_6$ ribbon with its 2-fold symmetries and of the i-phase

3.2. Magnetic behaviors

The magnetic behavior was investigated by zero field cooled (ZFC) and field cooled (FC) magnetization measurements. Fig. 3 shows the magnetization curves of the quasicrystal alloys $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ as a function of temperature under these two measurement configurations. For ZFC

measurement, the sample was cooled to 5 K in zero field and then measured up to 300 K in a field of 100 Oe, while the FC measurement was made by cooling the sample from 300 to 5 K in the same field. It clearly shows that there is a furcation between ZFC and FC curves at a certain temperature ($T = 290$ K), which is one of the characteristic features of a superparamagnetic system.

Table 1 The structure, H_c and M_r of $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ and TiVNi alloys

Sample	Structure	H_c (Oe)		M_r (emu/g)	
		15 K	300 K	15 K	300 K
$\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$	I, FCC, BCC	75.5	32.5	0.001	0.0004
TiVNi	FCC, BCC	40.7	29.8	0.0003	0.0002

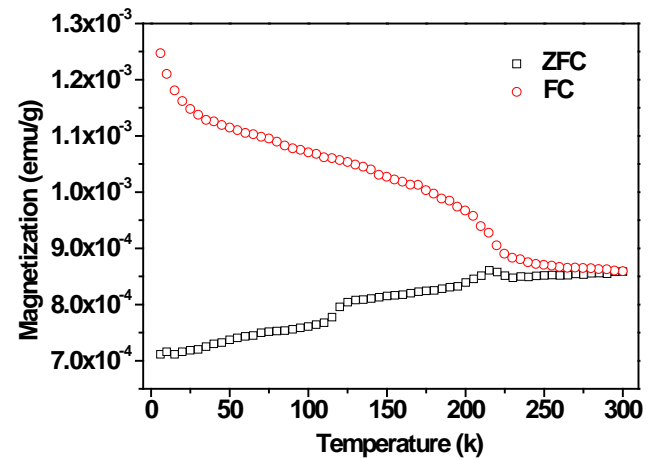


Figure. 3 Plot of magnetization of $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ quasicrystal for FC and ZFC processes at 100 Oe

We also measured the magnetization of $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ and TiVNi alloys as a function of an applied magnetic field (H) to understand the magnetic state of the quasicrystal at 15 K and 300 K, respectively. Visible hysteresis loop could be observed for both of the samples, as are shown in Fig. 4 and Fig. 5, which demonstrates that both alloys show ferromagnetic properties. But the coercive force (H_c) and the remanent magnetization (M_r) are very small, and the detailed values of H_c and the M_r are listed in Table 1, which demonstrates that they are soft magnetism.

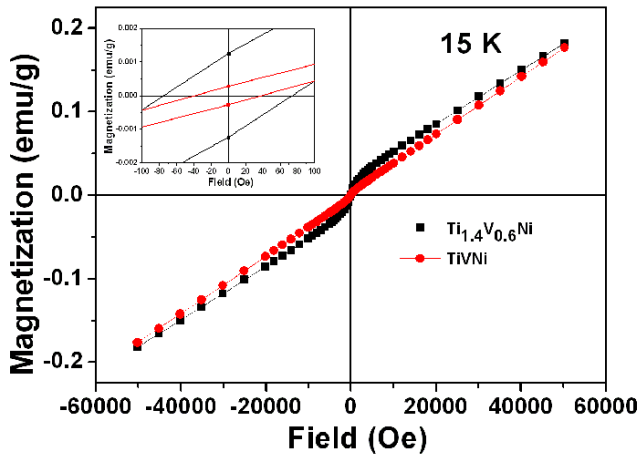


Figure. 4 Plots of magnetization of $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ alloy and TiVNi alloy as a function of applied magnetic field at 15 K

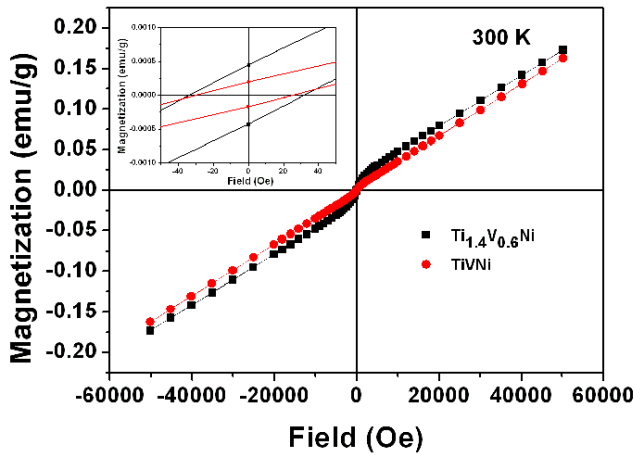


Figure.5 Plots of magnetization of $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ alloy and TiVNi alloy as a function of applied magnetic field at 300 K (b)

It is noticed that the magnetic properties of $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ and TiVNi alloys show some dependency on their structure, the I-phase will result in more contribution to the magnetization of the sample [14]. As mentioned above, the $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ alloy contains I-phase, Ti_2Ni -type face centered cubic (FCC) phase and body centered cubic (BCC) solid solution phase, while TiVNi alloy only contains Ti_2Ni -type face centered cubic (FCC) phase and body centered cubic (BCC) solid solution phase. In our results, as listed in Table 1, the H_c and the M_r of the $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ alloy, in which I-phase is involved, are higher than that of the TiVNi alloy. In both samples, Ni plays an important role in stabilization of the quasicrystal phase, and is the origination of the magnetic properties in the samples. Both in $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ and TiVNi alloys, the concentration of Ni is invariable, and the difference of their magnetic properties is resulted from their difference in structure when the ratio of Ti to V is varied, for both Ti and V show nonsignificant magnetic properties themselves. Therefore, it is reasonable to explain that the I-phase will make more contribution to their ferromagnetic properties.

Magnetic susceptibilities represented by the relation of $M=XH$, where X is the magnetic susceptibility, have positive

values for 25 K. It should be noted that there is magnetization fluctuation in the regions of relatively high applied magnetic field from -50000 to -10000 and from 10000 to 50000 at 25 K. In general, it is accepted that the magnetization of $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ quasicrystal is more stable at relatively high temperature and low applied magnetic field. This suggests that the magnetization stability of $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ quasicrystal is strongly influenced by temperature and by the intensity of applied magnetic field.

4. CONCLUSION

We prepared $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ and TiVNi alloys by melt-spinning technique. The phase was identified by using XRD. The $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ phase structures are composed by the icosahedral quasicrystal, Ti_2Ni , and BCC structural solid solution phase and the TiVNi phase structures are composed by Ti_2Ni and BCC structure solid solution phase. The magnetic behaviors of the samples were investigated, and their difference which resulted from varied structure was noticed and discussed. It is supposed that I-phase will make more contribution to the ferromagnetic properties of the $\text{Ti}_{1.4}\text{V}_{0.6}\text{Ni}$ and the TiVNi samples.

5. ACKNOWLEDGEMENTS

This work is financially supported by the Specialized Research Fund (Youth Teacher Category) for the Doctoral Program of Tertiary Education of the Ministry of the Education of China (20112216120001) and Foundation of the National Natural Science Foundation (21073179)

REFERENCES

- [1] R. M. Stroud, A. M. Viano, P. C. Gibbons, K. F. Kelton and S. T. Mixture, Appl. Phys. Lett. 69, 2998 (1996)
- [2] K. F. Kelton, W. J. Kim and R. M. Stroud, Lett. 70, 3230 (1997)
- [3] A. M. Viano, R. M. Stroud, P. C. Gibbons, A. F. McDowell, M. S. Conradi and K. F. Kelton, Phys. Rev. B. 51, 12026 (1995)
- [4] J. Y. Kim, R. Hennig, V. T. Huett, P. C. Gibbons and K. F. Kelton, J. Alloys. Compds. 404, 388 (2005)
- [5] W. J. Kim and K. F. Kelton, Phil. Mag. A. 72, 1397 (1995)
- [6] W. J. Kim and K. F. Kelton, Phil. Mag. Lett. 74, 439 (1996)
- [7] W. J. Kim, P. C. Gibbons and K. F. Kelton, Phil. Mag. A. 78, 1111 (1998)
- [8] A. Sadoc, J. Y. Kim and K. F. Kelton, Phil. Mag. A. 79, 2763 (1998)
- [9] S. Nimori, A. P. Tsai and G. Kido, Physica B. 237, 565 (1997)
- [10] D. Rau, J. L. Gavilano, Sh. Mushkolaj, C. Beeli and H. R. Ott J. Magn. Magn. Mater. 272, 1330 (2004)
- [11] M. Roy, J. Magn. Magn. Mater. 302, 52 (2006)
- [12] I. R. Fisher, Z. Islam, J. Zarestky, C. Stassis and M. J. Kramer, J. Alloys. Coumpds. 303 223 (2007)
- [13] J. Y. Kim, J. S. Schilling and K. F. Kelton, Solid. State. Communication. 105, 551 (1998)
- [14] Y. M. Lee, J. K. Jeon, H. M. Shin and J. Y. Kim, Z. Kristallogr. 224, 67 (2009)

- [15] V. Azhazha, A. Grib, G. Khadzhay, S. Malikhin, B. Merisov and A. Pugachov, Phys. Lett. A. 303, 87 (2002)
- [16] P. Termsuksawad, S. Niyomsoan, R. B. Goldfarb, V. I. Kaydanov, D. L. Olson and B. Mishra, J. Alloys. Compds. 373, 86 (2004)